R E P O R T R E S U M E S

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LABORATORY TRAINING EXERCISES 1-10, TEACHER AND STUDENT MANUAL. (TITLE SUPPLIED).

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DEVELOPED IN A CURRICULUM PROJECT, DESCRIBED IN VT 004 454, TO HELP YOUNG PEOPLE LEARN BASIC PRINCIPLES AND CONCEPTS OF MECHANICS AND TECHNOLOGY, THIS MANUAL PROVIDES TEACHERS AND STUDENTS WITH INSTRUCTIONS AND QUESTIONS RELATIVE TO 10 LABORATORY EXERCISES TO DEVELOP AN UNDERSTANDING OF THE OPERATION OF BASIC MACHINES. EXERCISES COVER (1) SIMPLE GEARS, (2) COMPOUND GEARS, (3) GEAR PROBLEMS, (4) FRICTION, (5) LEVERS, (6) THE WHEEL AND AXLE, (7) BELTS, PULLEYS, AND BEVEL GEARS, (8) THE INCLINED PLANE, (9) THE PULLEY, AND (10) WEIGH DETERMINATION. LABORATORY EXERCISES 11-18 ARE IN VT 004 471. THE TEACHER'S MATERIAL IS ON YELLOW PAGES, THE STUDENT'S ON BLUE. INSTRUCTOR SUGGESTIONS, ANSWERS TO PROBLEMS AND QUESTIONS, A PLAN OF PROCEDURE FOR EACH EXERCISE, AND EQUIPMENT LISTS ARE INCLUDED. THIS DOCUMENT IS MIMEOGRAPHED AND LOOSELEAF. OTHER RELATED DOCUMENTS ARE VT 004 455 THROUGH VT 004 471. (EM)

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Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 1

The George Washington University
Education Research Project
1966

SIMPLE GEARS

Objective

To develop an understanding of the operation of a simple gear set.

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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Materials

Item No.	Quantity	Description
1	2	80-Tooth Spur Gear
2	1	60-Tooth Spur Gear
3	3	40-Tooth Spur Gear
4	6	1/4"-20 Thumb Screws
5	6	1/4"-20 Plain Nuts
6	6	1/4"-20 Wing Nuts
7	1	Gear Mounting Board
8	2	1/4"-28 Nuts
9	1	Threaded Bushing
10	1	3/16"-24 Thumb Screw
11	1	3/16"-24 Wing Nut
12	1	3/16"-24 Plain Nut
13	5	Washers 1/4" diameter hole

NOTE: Items 8, 9, 10, 11 will not be needed until Exercise 2.

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.
2. It is very important that the gears turn freely on the thumb screw before mounting on the board. The nut should be tight enough to prevent the gear from being loose, but it should turn freely.
3. When sliding the gear to mesh with another they should mesh securely, but not so tight that they bind or stop.
4. Minor adjustments may be made by loosening the thumb screw slightly to allow the gear to turn more freely.

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5. The following points should be emphasized:

   a. When two gears are in mesh, the larger gear will turn fewer times than the smaller.

   b. When two gears are in mesh, they turn in opposite directions.

   c. When a large gear drives a small gear there is an increase in speed and a decrease in power.

   d. When a small gear drives a larger gear, there is a decrease in speed and an increase in power.

   e. In a gear train of three gears, the gear ratio is determined by the first and last gears in the train.

   f. In a gear train of three gears, the first and third gears turn the same direction.

   g. With gear trains of four gears, the first and last gears rotate in opposite directions.

6. Answers to the stated problems in the STUDENT'S MANUAL:

   S1-2 FEWER
   S1-3 OPPOSITE
   S1-3 POWER
   S1-3 POWER
   S1-4 SAME
   S1-4 OPPOSITE

7. Answers to the Questions in the STUDENT'S MANUAL:

   1. slower or fewer times
   2. opposite
   3. same
   4. same
   5. opposite
   6. power
   7. last

The George Washington University
Education Research Project
1966

SIMPLE GEARS

Purpose

To understand the operation of a simple gear set.

Materials

Item No.	Quantity	Description
1	2	80-Tooth Spur Gear
2	1	60-Tooth Spur Gear
3	3	40-Tooth Spur Gear
4	6	1/4"-20 Thumb Screws
5	6	1/4"-20 Plain Nuts
6	6	1/4"-20 Wing Nuts
7	1	Gear Mounting Board
8	2	1/4"-28 Nuts
9	1	Threaded Bushing
10	1	3/16"-24 Thumb Screw
11	1	3/16"-24 Wing Nut
12	1	3/16"-24 Plain Nut
13	5	Washers 1/4" diameter hole

NOTE: Items 8, 9, 10, 11 will not be needed until Exercise 2.

Step-by-Step Procedure

1. Notice the various sizes of gears. Put all six gears on top of one another and you will see there are two large gears, one middle size, and three small. The large gears have 80 teeth apiece, the middle size has 60 teeth, and the small gears have 40 teeth. These gears will be referred to by the number of teeth in the rest of the experiment.

2. Mount the one 80-tooth gear on a thumb screw through the center hole in the gear and screw a plain nut on behind it. Tighten the nut only until the gear will turn freely on the thumb screw.

> NOTE: The procedure on Page S1-1, Step 2, will be used when mounting any gear on the board in this exercise.

3. Mount all the gears on separate thumb screws by following the same procedure.

Gear trains with two gears

4. Mount one 80-tooth gear on the gear board by putting the threaded part of the thumb screw through the slot in the board and sliding it all the way to the left end of the slot.

5. Put a wing nut on the thumb screw and tighten it. The gear should turn freely.

6. Mount a 40-tooth gear on the board by repeating Steps 4 and 5 and sliding the gear up to the 80-tooth gear so they will mesh or contact each other.

> NOTE: When mounting gears, they should be in contact with each other so the teeth will mesh and the gears will rotate freely but not interfere with the turning action. This procedure will be followed when mounting any gear.

7. Make a mark with a grease pencil or marking pen across the two gears where they mesh.

8. Watch the mark on the 40-tooth gear and rotate the 80-tooth gear one complete turn. Notice the 40-tooth gear turns two turns for each turn of the 80-tooth gear.

WHEN TWO GEARS ARE IN MESH, THE LARGER GEAR WILL TURN _____ TIMES THAN THE SMALLER.

9. Turn the large gear clockwise and observe the direction of rotation of the small gear.

WHEN TWO GEARS ARE IN MESH, THEY
TURN IN _____ DIRECTIONS.

10. Put your finger lightly on the edge of the small gear and try turning the large gear. It is rather difficult to turn it.

WHEN A LARGE GEAR DRIVES A SMALL
GEAR, THERE IS AN INCREASE IN SPEED
AND THE _____ IS REDUCED.

11. Put your finger lightly on the edge of the large gear and try turning the small gear. Notice you can turn the gear rather easily.

WHEN A SMALL GEAR DRIVES A LARGE GEAR,
THERE IS A DECREASE IN SPEED AND THE
_____ IS INCREASED.

Gear treins with three gears

12. Mount the other 80-tooth gear next to the 40-tooth gear. (Steps 4, 5 and 6.)

13. Make a mark at the top of the second 80-tooth gear and rotate the first 80-tooth one complete turn. Notice the second 80-tooth gear makes only one turn.

IN A GEAR TRAIN OF THREE GEARS, THE
GEAR RATIO IS DETERMINED BY THE FIRST
AND LAST GEARS IN THE TRAIN.

14. Rotate the first 80-tooth gear clockwise and observe the direction of rotation of the second 80-tooth gear.

IN A GEAR TRAIN OF THREE GEARS,
THE FIRST AND THIRD GEARS TURN
THE _____ DIRECTION.

15. Check the power transmitted through the first and third gears as you did in Steps 10 and 11. Notice that there is no increase in speed and power.

Gear trains with four gears

16. Mount the 40-tooth gear next to the 80-tooth gear as you did in Step 12.

17. Observe the direction of rotation when the first 80-tooth gear is turned clockwise. Notice that it rotates in the opposite or counterclockwise direction.

WITH GEAR TRAINS OF FOUR GEARS, THE FIRST
AND LAST GEARS ROTATE IN _____ DIRECTIONS.

18. Make a mark at the top of the first and fourth gears and rotate the first gear with 80-teeth one complete turn. Notice the fourth gear with 40-teeth makes two turns, the same as the second 40-tooth gear.

IN ANY GEAR TRAIN WITH SIMPLE GEARS, THE GEAR RATIO IS DETERMINED BY THE FIRST AND LAST GEARS ONLY. THE GEARS IN THE MIDDLE DO NOTHING EXCEPT CHANGE THE DIRECTION OF ROTATION.

Gear trains with five or more gears

19. Mount the rest of the gears to make a gear train 5 or 6 gears long.

20. Make the following observations:
    a. every other gear turns the same direction,
    b. total gear ratio is determined by first and last gears in train.

21. Remove the gears from the board and rearrange them as you please.

QUESTIONS

1. When two gears are in mesh the larger gear will always turn _____ than the smaller.

2. When two gears are in mesh they will always turn in _____ directions.

3. When three gears are in mesh the end gears turn in the _____ direction.

4. When five gears are in mesh the end gears will turn the _____ direction.

5. When four gears are in mesh the end gears will turn in the _____ direction.

6. When a large gear and a small gear are in the mesh and the small gear is the driven gear there will be an increase in _____.

7. When five gears are in mesh the gear ratio is determined by the first and _____ gear in the train.

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COMPOUND GEARS

Objective

To develop an understanding of a compound gear set and how it differs from simple gears.

Materials

Item No.	Quantity	Description
1	2	80-Tooth Spur Gears
2	1	60-Tooth Spur Gears
3	3	40-Tooth Spur Gears
4	6	1/4"-20 Thumb Screws
5	6	1/4"-20 Plain Nuts
6	6	1/4"-20 Wing Nuts
7	1	Gear Mounting Board
8	2	1/4"-28 Nuts
9	1	Threaded Bushing
10	1	3/16"-24 Thumb Screw
11	1	3/16"-24 Wing Nut
12	1	3/16"-24 Plain Nut
13	5	Washers 1/4" diameter hole

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.
2. It may be necessary to obtain a pair of pliers before starting the exercise. The pliers may be necessary to tighten the nuts on the threaded bushing when making a compound gear.
3. Slight adjustments may be necessary when mounting the gears on the board. This can be done by adding washers between the board and the gears.
4. The gears should all turn freely when mounted on the board and should mesh with each other.

5. It is very important that the gears turn freely on the thumb screw before mounting on the board. The nut should be tight enough to prevent the gear from being loose but it should turn freely.

6. The following points should be emphasized:

   a. The purpose of a compound gear is to effect a large increase in speed or power without using a very large gear.

   b. Compound gears act the same in every other respect (direction change, increase in speed or power, and gear ratio determination) as simple gears.

7. Answers to the stated problems in the STUDENT'S MANUAL:

   S2-2 TWO

   S2-3 POWER

8. Answers to the Questions in the STUDENT'S MANUAL:

   1. large
   2. same
   3. two

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 2

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1966

COMPOUND GEARS

Purpose

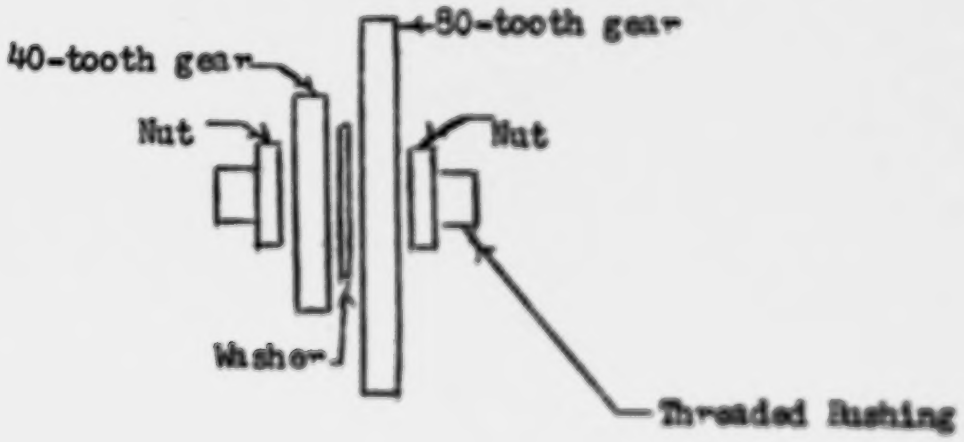
To understand how compound gears operate.

Materials

Item No.	Quantity	Description
1	2	80-Tooth Spur Gears
2	1	60-Tooth Spur Gear
3	3	40-Tooth Spur Gears
4	6	1/4"-20 Thumb Screws
5	6	1/4"-20 Plain Nuts
6	6	1/4"-20 Wing Nuts
7	1	Gear Mounting Board
8	2	1/4"-28 Nuts
9	1	Threaded Bushing
10	1	3/16"-24 Thumb Screw
11	1	3/16"-24 Wing Nut
12	1	3/16"-24 Plain Nut
13	5	Washers 1/4" diameter hole

Step-by-Step Procedure

1. Put one nut on the threaded bushing.
2. Slide a 40-tooth gear over the bushing.
3. Put one washer over the bushing on top of the gear.
4. Slide an 80-tooth gear over the bushing.
5. Screw a nut over the bushing and tighten it. The arrangement should look like this picture, but with all parts close to each other.



6. Mount this unit, called a compound gear unit because it has two gears connected together, in the center of the slot in the gear board using the following procedure:

   a. Insert a 3/16" diameter thumb screw through the bushing.

   b. The 40-tooth gear should be on top.

   c. Put a nut on the part of the screw that comes through the bushing.

   d. Put a washer over the screw.

   e. Put the unit through the slot in the board.

   f. Put on a washer.

   g. Put on a wing nut and tighten the unit to the board. The gear unit should turn freely.

A COMPOUND GEAR UNIT HAS _____ GEARS FASTENED TOGETHER ON THE SAME SHAFT.

7. Mount a 40-tooth gear to the left of the compound gear using the procedure followed in Exercise 1, but add three washers above the gear board to raise the gear so it will mesh with the 80-tooth gear on the compound gears.

8. Mount an 80-tooth gear to the right of the compound gear unit by using two nuts and three washers to raise the gear to mesh with the 40-tooth gear on the compound unit.

9. Make a mark at the top of the 40-tooth gear on the left and the 80-tooth gear on the left.

10. Rotate the 40-tooth gear on the right one complete turn. Observe that the 80-tooth gear makes one-quarter of a revolution, making a four to one gear reduction.

11. Try holding the 80-tooth gear while rotating the 40-tooth gear. Notice you can turn the 40-tooth gear quite easily.

> NOTE: The 40-tooth gear on the left meshes with the 80-tooth gear in the center making a two to one reduction. The 40-tooth gear mounted on the same shaft as the 80-tooth gear meshes with the 80-tooth gear on the right making another two to one reduction or a total of four to one.

12. Turn the 80-tooth gear on the right one complete revolution and notice the 40-tooth gear on the left makes four revolutions.

13. Try holding the 40-tooth gear and turning the 80-tooth gear. Notice you can hold it quite easily. There is an increase in speed but a reduction in power in this type of a gear train.

A COMPOUND GEAR CAN BE USED TO ACHIEVE LARGE INCREASES IN SPEED OR _____ WITHOUT USING A VERY LARGE GEAR.

14. Try mounting the 60-tooth gear in place of the 40-tooth gear on the compound gear unit and repeat Steps 9 through 13. Observe the results by changing this gear.

QUESTIONS

1. A compound gear unit can make _____ changes of speed or power without using very large gears.

2. A compound gear unit acts the _____ as a simple gear unit when determining direction of rotation.

3. A compound gear unit has _____ gears on the same shaft.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 3

The George Washington University
Education Research Project
1966

SOLVING GEAR PROBLEMS

Objectives

To develop an appreciation and understanding of how gear trains operate and how they may be used to solve specific problems.

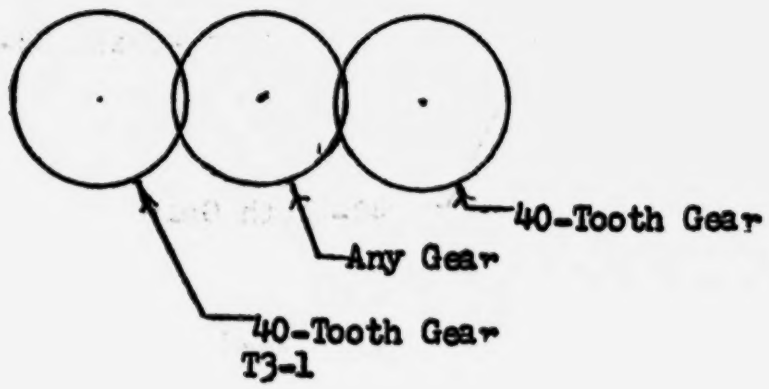
Materials

Item No.	Quantity	Description
1	2	80-Tooth Spur Gears
2	1	60-Tooth Spur Gear
3	3	40-Tooth Spur Gears
4	6	1/4"-20 Thumb Screws
5	6	1/4"-20 Plain Nuts
6	6	1/4"-20 Wing Nuts
7	1	Gear Mounting Board
8	2	1/4"-28 Nuts
9	1	Threaded Bushing
10	1	3/16"-24 Thumb Screw
11	1	3/16"-24 Wing Nut
12	1	3/16"-24 Plain Nut
13	5	Washers 1/4" diameter hole

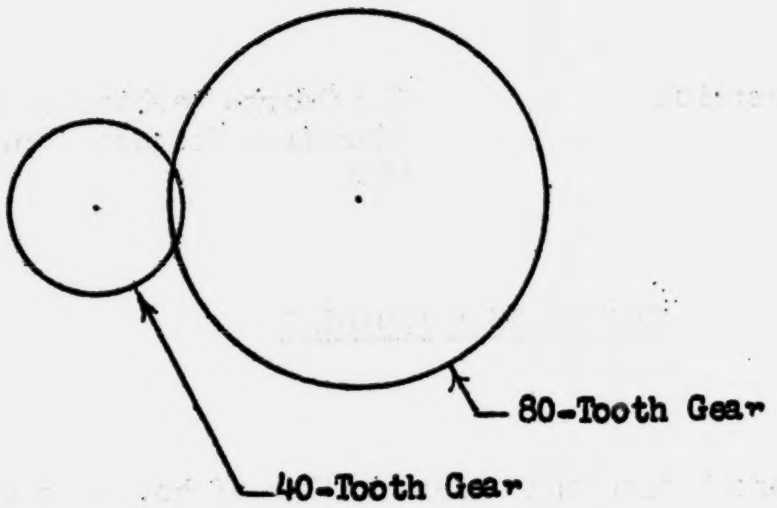
Suggestions to the Instructor

1. This is an optional exercise that may be performed as the time permits.
2. This exercise should not be attempted unless the students have a thorough understanding of Exercises 1 and 2.
3. Emphasize the method of mounting gears as demonstrated in Exercises 1 and 2.
4. The solutions to the Problems as shown below may not be the only answers or methods of solving the problem. Check the student's work to see that the problem is solved correctly.
5. Answers to the Problems:

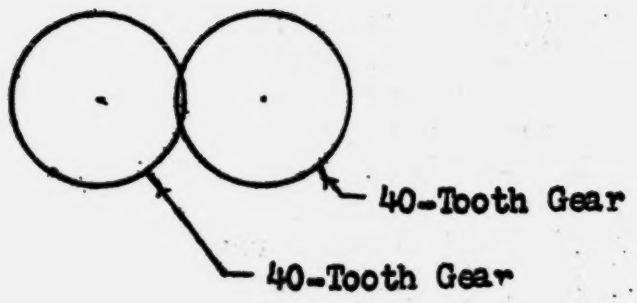
1.



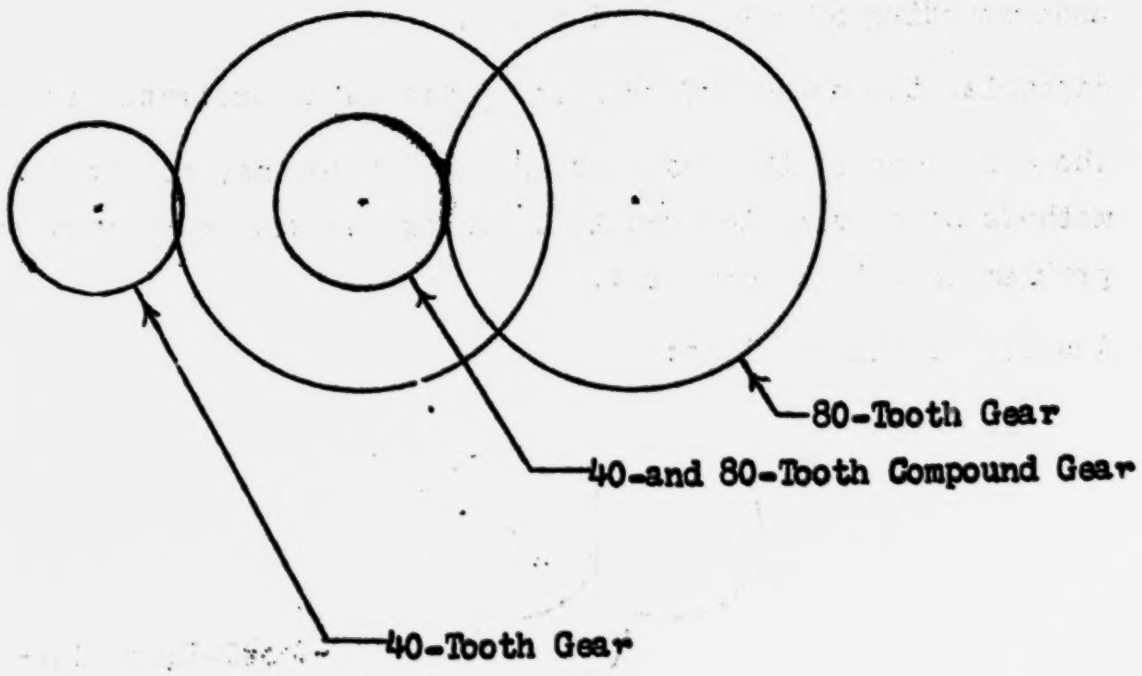
2.


80-Tooth Gear
40-Tooth Gear

3.


40-Tooth Gear
40-Tooth Gear

4.


80-Tooth Gear
40-and 80-Tooth Compound Gear
40-Tooth Gear

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 3

The George Washington University
Education Research Project
1966

SOLVING GEAR PROBLEMS

Purpose

To develop gear trains that will do a specific job.

Materials

Item No.	Quantity	Description
1	2	80-Tooth Spur Gears
2	1	60-Tooth Spur Gear
3	3	40-Tooth Spur Gears
4	6	1/4"-20 Thumb Screws
5	6	1/4"-20 Plain Nuts
6	6	1/4"-20 Wing Nuts
7	1	Gear Mounting Board
8	2	1/4"-28 Nuts
9	1	Threaded Bushing
10	1	3/16"-24 Thumb Screw
11	1	3/16"-24 Wing Nut
12	1	3/16"-24 Plain Nut
13	5	Washers 1/4" diameter hole

Step-by-Step Procedure

1. In this exercise it will be necessary to use the information gained in Exercises 1 and 2. Compound or simple gears may be used. Gear reduction or increase will be specified and the direction of rotation.
2. First determine what gears must be used and then mount them on the board to perform the reduction.

Problems

1. Make a gear unit with a one to one ratio with the end gears turning the same direction.
2. Make a gear unit with a two to one reduction with the gears turning the opposite direction.
3. Make a gear unit with a one to one ratio with the gears turning opposite directions.
4. Make a gear unit with a four to one ratio with the gears turning the same direction.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 4

The George Washington University
Education Research Project
1966

FRICTION

Objective

To demonstrate what friction is and how it works.

Materials

Item No.	Quantity	Description
1	1	Friction Block (This is a 4" x 1 3/4" x 1" wooden block. A hook is in one end and two holes are in the top.)
2	1	Friction Platform (This is the 16" x 2 1/2" x 3/8" board with a piece of half-round molding at one end.)
3	2	Pegboard Hooks
4	2	Wood Dowels, 1/2" diameter x 2" long
5	3	1-ounce Weights
6	1	4-ounce Weights
7	1	5-ounce Weights
8	2	S Hooks
9	10	Rubber Bands, 1/2" diameter
10	5	Rubber Bands, 2" diameter
11	1	Sandpaper
12	1	18-inch String
13	1	Paper Clip Hook
14	1	Spring Scale
15	25	Washers, 1/4" diameter hole

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.
2. Student comment and discussion is desirable throughout the demonstration.
3. The teacher, in order to encourage discussion, may wish to ask questions and make comments regarding the relationships that exist between this laboratory exercise and its application as found in the materials, tools, and machines the student encounters in his environment.

a. See if anyone can explain friction.
b. Give examples of friction.
c. Rub your hands together and demonstrate slipping and generation of heat.
d. What relationship do fingerprints have to friction?

4. If there is time in the class period, the student may be permitted to do the optional procedures suggested in Steps 24 through 27 or any others the teacher and students might think are interesting and worthwhile.

5. The following principles have been demonstrated by this exercise:
   a. More force is needed to slide objects over a rough surface than a smooth surface.
   b. Rolling friction is less than sliding friction.
   c. More force is needed to move a heavy object than a light one.
   d. More force is necessary to start an object moving than to keep it moving.

6. Answers to the blanks left in the stated principles in the STUDENT'S MANUAL:

   S4-3 MORE
   S4-4 HEAVY
   S4-4 MORE

7. Answers to Questions in Student's Exercise:
   1. greater
   2. less
   3. less
   4. a. Make the surfaces in contact smoother
      b. Use wheels or rolling friction
      c. Reduce the weight of the object to be moved

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 4

The George Washington University
Education Research Project
1966

FRICTION

Purpose

This exercise will help you understand what friction is and how it works.

Materials

Item No.	Quantity	Description
1	1	Friction Block (This is a 4" x 1 3/4" x 1" wooden block. A hook is in one end and two holes are in the top.)
2	1	Friction Platform (This is the 16" x 2 1/2" x 3/8" board with a piece of half-round molding at one end.)
3	2	Pegboard Hooks
4	2	Wood Dowels, 1/2" diameter x 2" long
5	3	1-ounce Weights
6	1	4-ounce Weights
7	1	5-ounce Weights
8	2	S Hooks
9	10	Rubber Bands, 1/2" diameter
10	5	Rubber Bands, 2" diameter
11	1	Sandpaper
12	1	18-inch String
13	1	Paper Clip Hook
14	1	Spring Scale
15	25	Washers, 1/4" diameter hole

Step-by-Step Procedure

Preparing materials and setting up the board

1. Insert pegboard hooks in the holes in one side of the platform. The half-round molding is on the upper side of the platform.
2. Put the platform on the pegboard so that it is horizontal and about in the center of the pegboard.

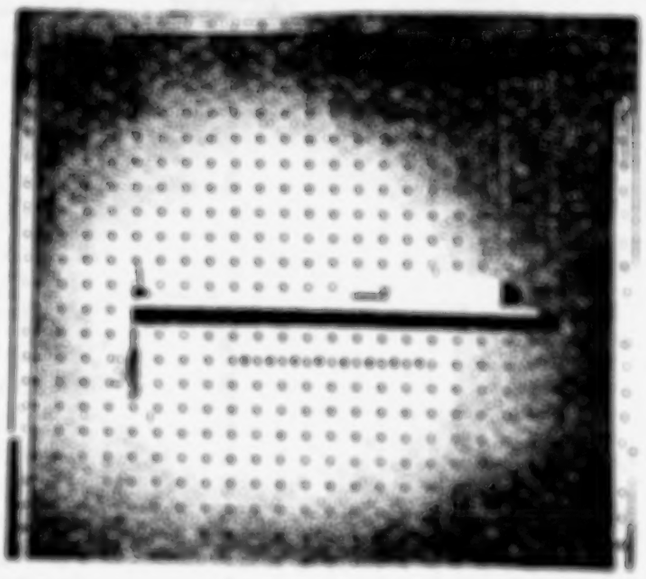
3. Make a loop in each end of the 13-inch piece of string. Do this by doubling one end of the string back about four inches and tying a simple knot in the doubled end. Then do the same thing on the other end.

4. Get a rough estimate of the weight of the friction block by weighing it with the spring scale. Write the weight on the side of the block. Notice that the block weighs a little more than one ounce.

Sliding friction

5. Attach one loop of the string to the hook of the block and put an S hook in the other end.

6. Place the block on the end of the platform away from the half-round molding with the S hook hanging over the molding.



NOTE: When these instructions call for placing the friction block on the platform, always place it at the end of the platform away from the half-round molding, with the string and S hook hanging over the molding.

7. Hang a 1-ounce weight and add washers on the S hook until the block moves. This will take about one to five washers plus the weight.

8. Remove the paper clips and S hook and insert the hook of the spring scale.

9. Pull the block by the spring scale along the platform horizontally, observing the reading as you do so. This reading will be very small, if there is any reading at all.

10. Remove everything from the platform.

11. Push the hook of the friction platform through the sandpaper and fold it under the bottom of the block.

12. Place the block, with the string and S hook attached, on the platform.

13. Hang a 1-ounce weight on the S hook and add washers until the block moves. It may be necessary to make a hook from a paper clip to hold the washers. You will find that it takes from 15 to 25 washers to move it over the platform.

14. Remove the weight, washers and S hook and insert the hook of the spring scale.

15. Pull the block along the platform and observe the reading on the scale as you do so. This reading will be more than without the sandpaper on the block.

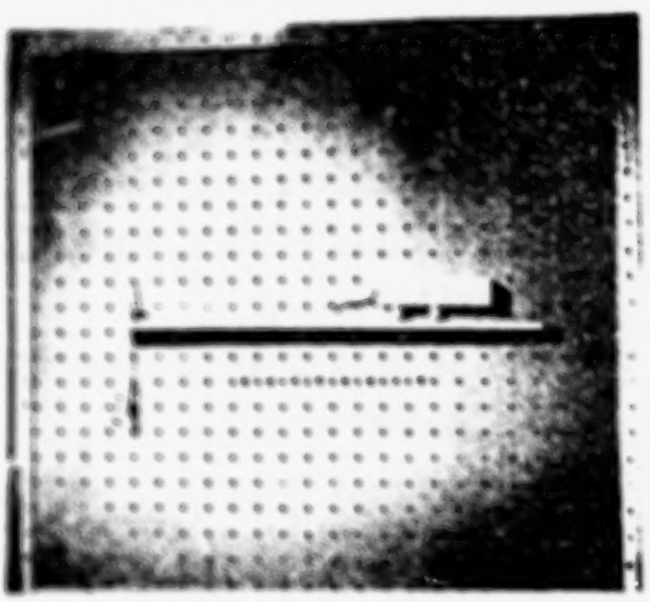
THIS SHOWS THAT _____ FORCE IS NEEDED TO SLIDE OBJECTS OVER A ROUGH SURFACE.

Rolling friction

16. Remove the spring scale from the string and the sandpaper from the platform.

17. Place the block on the platform with two dowels under it, one inch apart, as in the picture opposite.

18. Hang washers, one at a time, to the S hook to see how many it takes to move the block.



Friction and its relationship to force

19. Remove everything from the platform.

20. Place the block on the platform but this time put one 4-ounce weight in the hole in the top of the block.

21. Hang two 1-ounce weights from the S hook. You will probably find that this will not move the block. Hang washers or another 1-ounce weight to the hook until the block moves.

THIS SHOWS THAT IT TAKES MORE FORCE TO MOVE A _____ WEIGHT THAN A LIGHT ONE.

22. Remove the weights from the S hook and insert the hook end of the spring scale.

23. Pull the block along the platform and observe the reading on the scale as you do so. This reading will be more than without the weights. Notice also that the spring scale reads more when starting the block moving than when keeping it moving.

THIS SHOWS THAT IT TAKES _____ FORCE TO START AN OBJECT MOVING THAN IT DOES TO KEEP IT GOING.

If there is time left during the period, do some of the following:

24. See what force it takes to move the block when it slides on its side.

25. See what force it takes to pull a 5-ounce weight along the platform.

26. See what force it takes to pull the block with rubber bands around it lengthwise.

27. See what force it takes to slide the following things over the platform:

    a. blackboard eraser
    b. full box of paper clips
    c. glass paperweight
    d. pocket comb
    e. keys
    f. a book

QUESTIONS

1. The rougher the surface, the _____ the friction.

2. The smoother the surface, the _____ the friction.

3. The force needed to keep an object moving is _____ than that required to start it moving.

4. Name three ways to reduce the force needed to move an object.

    a. _____
    b. _____
    c. _____

Laboratory Training Exercises
TEACHER'S MANUAL
Exercise 5

The George Washington University
Education Research Project
1966

LEVERS

Objective

To demonstrate how the three classes of levers work.

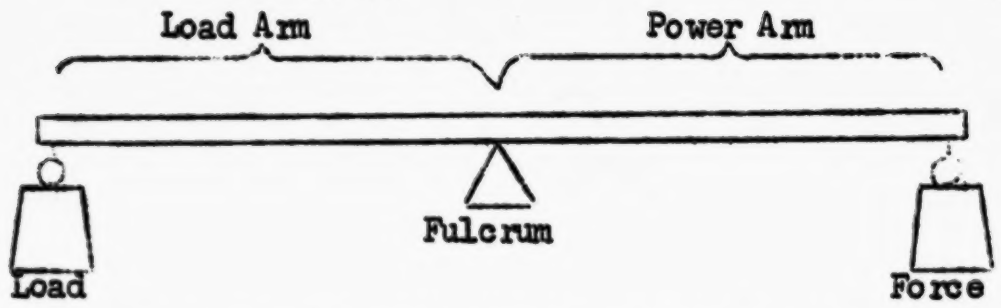
Materials

Item No.	Quantity	Description
1	1	Lever Arm
2	4	Weights, 1-ounce
3	3	Pegboard Hooks
4	1	Spring Scale
5	10	Bands, Rubber (small)
6	2	Paper Clip Hooks

Suggestions to the Instructor

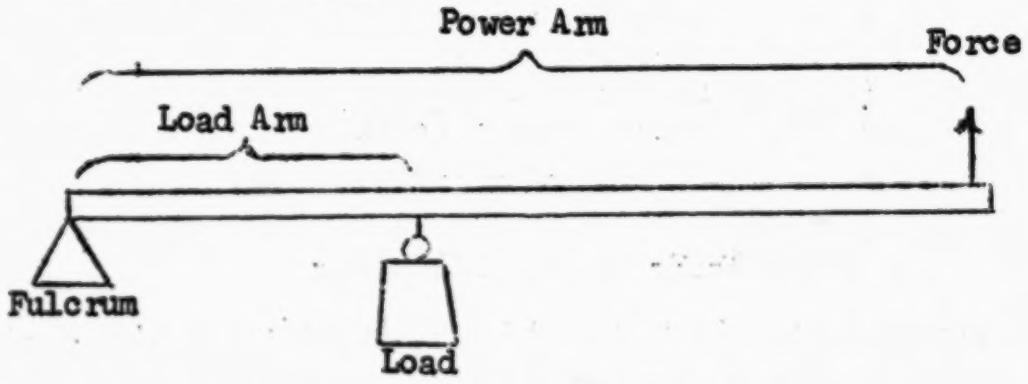
1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by Step Procedure section.
2. The teacher and students may find it easier to change the paper clip hooks and weights when the lever arm is removed from the pegboard hook.
3. To obtain a balance with the lever arm does not mean the lever arm has to be level. An approximate balance is obtained if the lever arm is nearly horizontal.
4. In Step 37, a piece of string may be used instead of the rubber band, if this is more convenient.
5. The exercise has been designed to facilitate class discussion. Encourage student comment and discussion to check accuracy of observation and concept development, as well as to stimulate and maintain student interest in the demonstration.
6. The teacher, through questions and comments, should emphasize the relationship of the laboratory exercise being demonstrated and its application in the tools and machines used every day. The three classes of levers are determined by the relationships of the load, the applied force, and the fulcrum. To be able to identify the three classes of levers easily, it is necessary that these three relationships be recognized readily by the student

a. First-class lever:



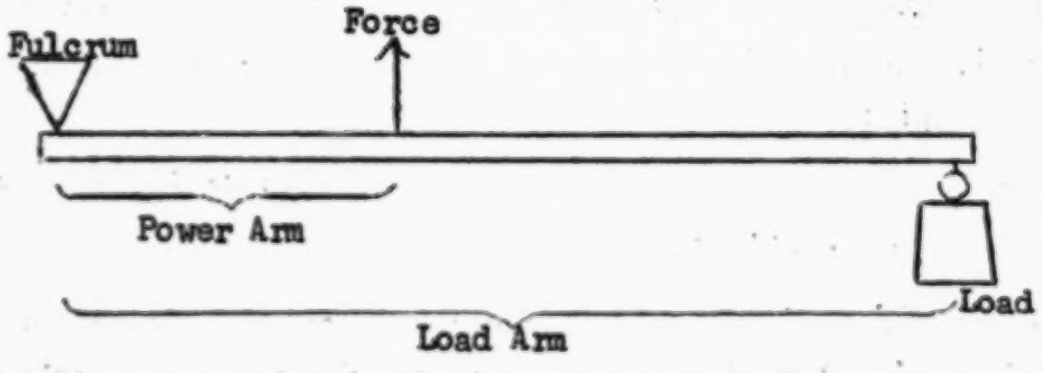
Examples of application of the first-class lever:
stick (prying), wrenches, crowbar, shears, pliers, scissors, control levers, steering wheel, door knob.

b. Second-class lever:



Examples of application of the second-class lever:
nutcracker, bottle opener, wheelbarrow, can opener (lever type).

c. Third-class lever:



Examples of application of the third-class lever:
baseball bats, golf clubs, shovels, mouse traps, and grass shears.

7. At the end of the demonstration the teacher may wish to ask the students to list as many examples of each type of lever as they can think of. The pupils could report their findings at the beginning of the next period devoted to Exercise 5.

Suggestions for Additional Tasks

Depending upon the time available and the interest and aptitude of the students, the following additional steps are suggested as being applicable to this exercise:

8. First-class levers
   Show that the 1-ounce weights balance in all holes equidistant from the fulcrum--that is, L6 and R6, L5 and R5, etc.

9. Other type levers
   Experiment with various combinations of weights.

10. Answers to the blanks left in the stated principles in the STUDENT'S MANUAL:

    S5-2 EQUAL
    S5-3 TWICE
    S5-3 THREE
    S5-3 SMALLER
    S5-5 FULCRUM
    S5-5 GREATER
    S5-7 LOAD

11. Answers to questions in STUDENT'S MANUAL:

    1. power
    2. fulcrum
    3. fulcrum
    4. balance
    5. twice
    6. four times
    7. load
    8. smaller
    9. force
    10. smaller

The George Washington University
Education Research Project
1966

LEVERS

Purpose

This exercise will help you understand how levers work.

Materials

Item No.	Quantity	Description
1	1	Lever Arm
2	4	Weights, 1-ounce
3	3	Pegboard Hooks
4	1	Spring Scale
5	10	Bands, Rubber (small)
6	2	Paper Clip Hooks

Step-by-Step Procedures

Working with a first class lever

1. Put one of the 6-inch wire pegboard hooks in the center of the pegboard stand. Row 6, holes M and N. This wire pegboard hook will be the fulcrum for the lever.
2. Place a paper clip hook in hole number 7 at each end of the lever arm.
3. Hang a 1-ounce weight from the hook in hole 7 on the left side of the lever arm.

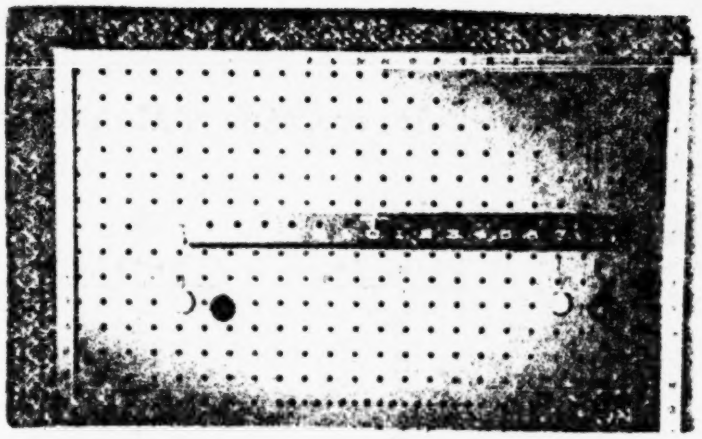
> NOTE: From here on, we will use symbols to refer to holes above the numbers on the lever arm. L and a number will refer to holes left of the 0 hole, and R and a number will refer to holes right of the 0 hole. For example: L7 will refer to the seventh hole to the left of the center and R5 will refer to the fifth hole to the right of the center.

4. Hang another 1-ounce weight in hole R7.

5. Put the lever arm with the weights already in place on the mounting fixture through hole 0. The numbers on the lever arm should be facing you.

6. Observe that the 1-ounce weights balance each other (approximately), when they are hung the same distance from the fulcrum.

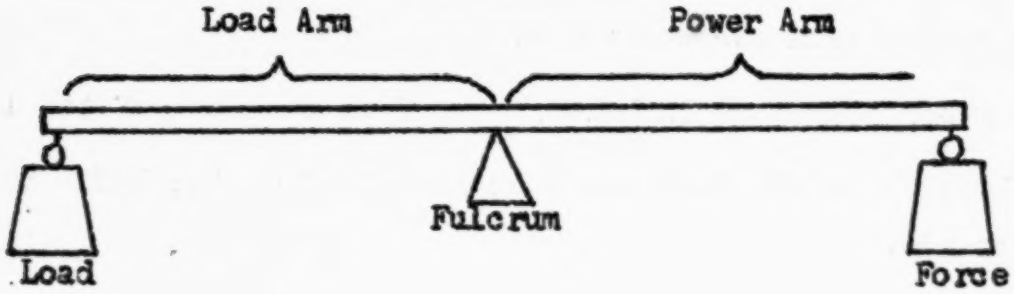
THIS ILLUSTRATES THAT WITH SIMPLE OR FIRST-CLASS LEVERS, _____ WEIGHTS AT EQUAL DISTANCES FROM THE FULCRUM BALANCE EACH OTHER.



SET-UP FOR FIRST-CLASS LEVER

7. Remove both 1-ounce weights and paper clip hooks from the lever arm.

Diagram of a First-Class Lever



8. Place two 1-ounce weights on one of the paper clip hooks and hang from hole L2. Hang a 1-ounce weight from hole R2. Notice that they do not balance each other.

9. Try to balance two 1-ounce weights by hanging the 1-ounce weight from various holes on the right side of the lever arm. You will find the weights will balance (approximately) when the 2-ounce weight is in hole R4.

10. Move the two 1-ounce weights to hole L3 and again see where you must hang the 2-ounce weight to make the lever arm balance. You will find that it will balance (approximately) when the 2-ounce weight is in hole L6.

THIS SHOWS THAT WITH A FIRST-CLASS LEVER, A WEIGHT BALANCED WITH ANOTHER WEIGHT TWICE AS HEAVY WILL BE _____ AS FAR FROM THE FULCRUM.

11. Remove the weights and hooks from the lever arm.

12. Place three 1-ounce weights on the same hook and hang from hole L2. See where you have to hang the 1-ounce weight on the other side of the lever arm to balance it. You will find that it will have to be placed in hole R6.

THIS SHOWS THAT WITH A FIRST-CLASS LEVER, A WEIGHT BALANCED WITH ANOTHER WEIGHT THREE TIMES AS HEAVY WILL BE _____ TIMES AS FAR FROM THE FULCRUM.

13. With three 1-ounces in hole L2 balanced with one 1-ounce in hole R6 as in the previous step, pull down one end of the lever arm several inches and then release it.

14. After releasing the lever arm notice the arc (distance of movement) made by each weight. Notice that the arc made by the 1-ounce of weight is about three times longer than that made by the three 1-ounce weights. A diagram of this action follows:

THIS SHOWS THAT WITH FIRST-CLASS LEVERS THE _____ WEIGHT MOVES THROUGH A GREATER DISTANCE THAN THE LARGER WEIGHT.

15. Remove everything from the pegboard.

Working with second-class levers

16. Mount one of the wire pegboard hooks in the upper right corner of the pegboard, Row 4, holes T-U.

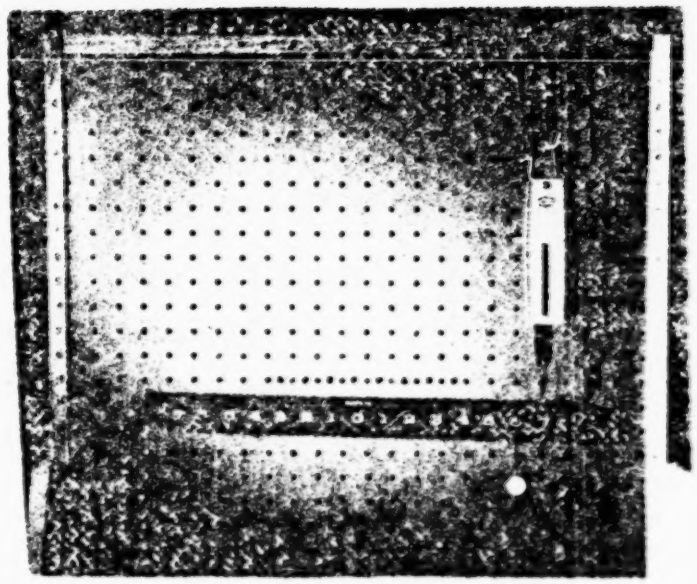
17. Mount a second wire pegboard hook in Row 14, holes E-F.

18. Hang the spring scale on the first pegboard hook.

19. Place the hook of the spring scale through hole R7 of the lever arm.

20. Put the other end of the lever arm on the left pegboard hook using hole L7. The lever arm should be approximately level.

21. Read the spring scale and record your reading on the chart below.



SET-UP FOR SECOND-CLASS LEVER

22. Hang two 1-ounce weights from hole R6. Record the reading below.

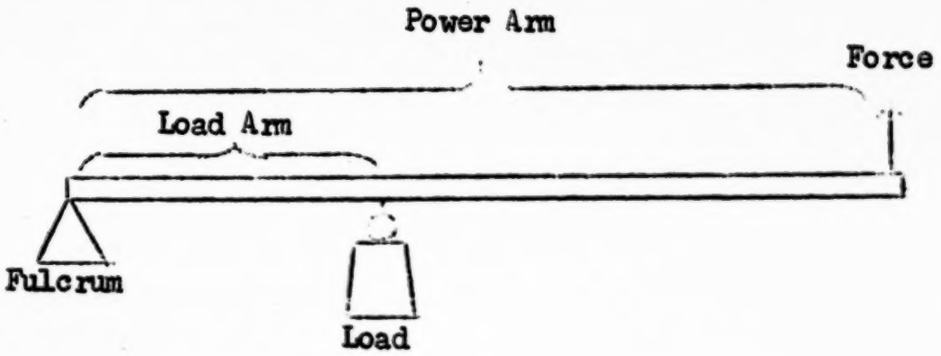
Weight	Hole	Scale Reading	Weight	Hole	Scale Reading
0	0		2 oz.	0	
2 oz.	R6		2 oz.	L3	
2 oz.	R3		2 oz.	L6	

23. Move the two 1-ounce weights from hole R6 to hole R3. Record the reading above.

24. Move the two 1-ounce weights from hole R3 to hole 0. Record the reading of the scale on the chart.

25. Continue to move the weight to the left and record your readings of the scale on the chart.

Diagram of a Second-Class Lever



26. Observe that the reading continues to decrease each time the weight is moved closer to the fulcrum.

THIS SHOWS THAT IN SECOND-CLASS LEVERS, THE CLOSER THE LOAD ON THE LEVER BAR IS TO THE _____, THE SMALLER THE FORCE REQUIRED TO LIFT IT.

27. Remove the weight but leave the hook in hole L6.

28. Hang four 1-ounce weights on the hook in hole L6.

29. Move the weights and hook to holes L3, 0, R3, and R6 observing the arc made by each hole on the arm. Notice that not only did the scale reading increase but also the length of the arc increased as the weights were moved from left to right on the lever arm.

THIS SHOWS THAT AS THE LOAD ARM LENGTHENS, THE POWER ARM MOVES THE _____ DISTANCE FOR THE SAME AMOUNT OF LOAD.

Working with third-class levers

30. Remove everything from the pegboard.

31. Mount one of the pegboard hooks in Row 2, holes M-N.

32. Hang the scale from this pegboard hook.

33. Insert the hook of the spring scale into hole O of the lever arm.

34. Mount a second pegboard hook in Row 12, holes E-F of the board, with the point of the hook pointing <u>downward</u>.

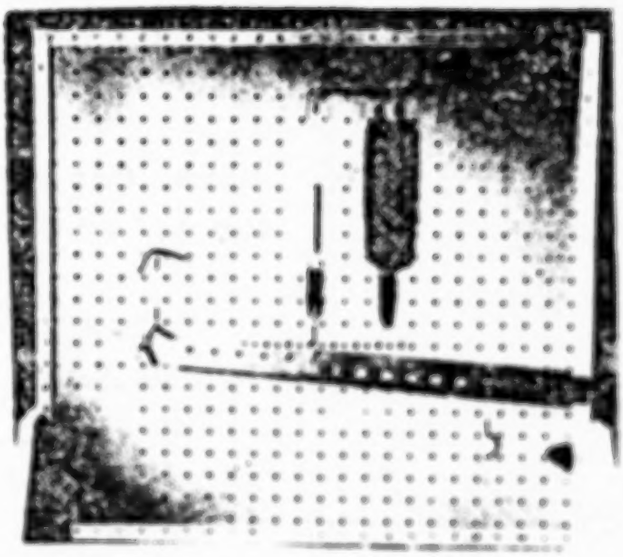
35. Place the end of the second pegboard hook through hole L7 of the lever arm. This is the fulcrum.

36. Mount the third pegboard hook in Row 9, holes E-F, with the point of the fixture pointing <u>upward</u>.

37. Stretch a rubber band over the ends of the second and third hooks.

38. Record the reading on the spring scale on the chart on the next page.

39. Insert a hook in hole R7.

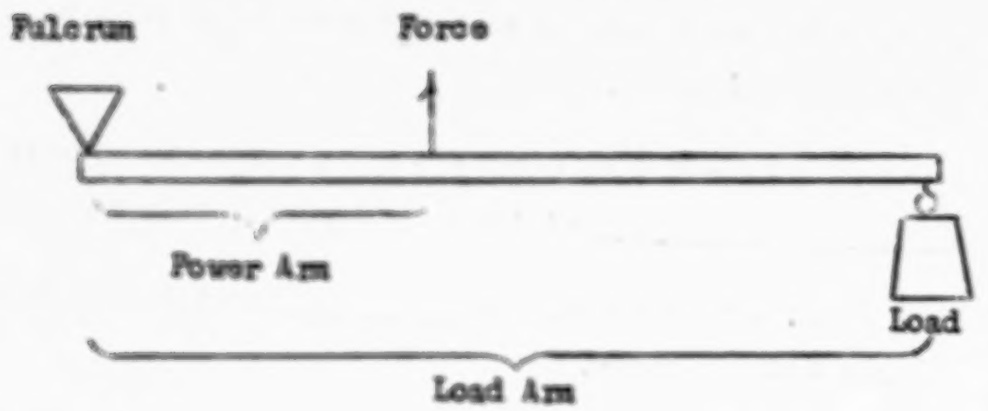


SET-UP FOR THIRD-CLASS LEVER

40. Place two 1-ounce weights on the hook. Record reading on spring scale.

Weight	Hole	Scale Reading	Weight	Hole	Scale Reading
2 oz.	0		2 oz.	B4	
2 oz.	B2		2 oz.	B6	

Diagram of Third-Class Lever



41. Move the first pegboard hook and the hook of the spring scale in successive steps to B2, B4, and B6. Do this in the manner you feel is easiest for you. Each time you move the pegboard hook, it will be placed two holes to the right of the position it held before. Record the readings on the spring scale each time.

THIS SHOWS THAT IN THIRD-CLASS LEVERS,
THE CLOSER THE APPLIED FORCE IS TO THE
_____, THE SMALLER IT IS.

QUESTIONS

1. A lever bar has two arms, the load arm and the _____ arm.

2. The point on which the lever bar moves is the _____.

3. In a first-class lever, the _____ is located between the load and the force.

4. When equal weights are placed on a lever arm at equal distances from the fulcrum, they _____ each other.

5. A weight balanced with another twice as heavy will be _____ as far from the fulcrum.

6. A weight balanced with another four times as heavy will be _____ _____ as far away from the fulcrum.

7. In a second-class lever, the _____ must be located between the fulcrum and the force.

8. The closer the load on the lever arm of a second-class lever is to the fulcrum, the _____ the force needed to lift it.

9. In a third-class lever, the _____ is located between the fulcrum and load.

10. The closer the force on the lever arm of a third-class lever is to the load, the _____ the force needed to lift it.

The George Washington University
Education Research Project
1966

THE WHEEL AND AXLE

Objective

To demonstrate the mechanical advantage of the wheel and axle.

Materials

Item No.	Quantity	Description
1	1	Pegboard Hook
2	1	Wheel and Axle Set
3	2	S Hooks
4	4	1-ounce Weights
5	3	3-ounce Weights
6	1	Paper Clip Hook
7	2	18-inch String

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.

2. Careful measurement of the small wheel will reveal that the exact relationship is not quite three to one, however the friction that is present will give in proper results.

3. Encourage student discussion before the demonstration on various wheel and axle combinations with which they are already familiar. Some examples are the wheel and axle of an automobile, various types of cranks and winches, the wheels and axles of a rotary lawn mower, (Do bigger wheels mean it is easier to push bicycles?), (Does a smaller sprocket on the back wheel mean the bicycle is easier to pedal or will it go faster?), and any other type of wheel and axle that may be mentioned in the discussion.

4. The mathematics of the relationship of the wheel and axle should be demonstrated on a blackboard. Emphasize that either diameter or radius of the wheel and axle can be used as long as both measurements are either radius or diameter.

5. To further demonstrate the distance that each wheel travels in one revolution, roll the three different diameters of the wheels along the edge of a desk or table and mark the distance each travels in one revolution.

6. Answers to the blanks left in the stated principles in the STUDENT'S MANUAL:

   36-3 FORCE
   36-3 LOAD
   36-4 DISTANCE
   36-4 DISTANCE

7. Answers to the questions in the STUDENT'S MANUAL:

   1. three
   2. nine
   3. twelve
   4. more
   5. less
   6. further

The George Washington University
Education Research Project
1966

THE WHEEL AND AXLE

Purpose

This exercise will help you understand how the wheel and axle work.

Materials

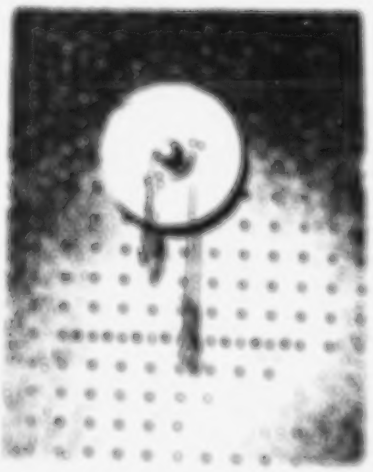
Item No.	Quantity	Description
1	1	Pegboard Hook
2	1	Wheel and Axle Set
3	2	S Hooks
4	4	1-ounce Weights
5	3	3-ounce Weights
6	1	Paper Clip Hook
7	2	18-inch String

Step-by-Step Procedure

1. Place the pegboard hook in Row 7, holes H and H.
2. Place the wheel and axle set over the pegboard hook.
3. Tie a loop in one end of one of the 18-inch strings. Do this by doubling the string back about two inches and tying a single knot in the doubled end.
4. Tie the other end of the 18-inch string around the wooden dowel center axle.
5. Wrap the 18-inch string around the 1/2-inch axle by turning the 4 1/2-inch wheel clockwise.
6. Take the other 18-inch string and tie a loop in each end by repeating Step 3.
7. Place one loop of this string over the hook on the 1 1/2-inch blue wheel and lead it out through the opening opposite the hook.
8. Wrap this string one complete turn around the blue wheel in a clockwise direction.

3. Hang an S hook in each of the loops that are hanging down.

4. Compare your set-up with the picture below.



5. Hang a 1-ounce weight on the string on the right hand side.

6. Hang three 1-ounce weights on the string on the left hand side.
Notice that the one 1-ounce weight balances the three 1-ounce weights.

Large Wheel
1/4" Radius

Small Wheel
/4" Radius

Axle
/4" Radius

Large Wheel
4 1/2" Diameter

Small Wheel
1 1/2" Diameter

Axle
1/2" Diameter

5½"

NOTE: The wheel and axle function as a first-class lever. (Refer to Exercise 5.) The center of the axle (wooden dowel) is the fulcrum, the distance from the center of the axle to the outside edge of the axle is the load arm, and the distance from the center of the blue wheel to the outside edge is the power arm. In this case 3/4 inch divided by 1/4 inch equals 3 or a 3 to 1 mechanical advantage.

THIS SHOWS THAT WITH A WHEEL AND AXLE SET, WHEN THE WHEEL IS THREE TIMES THE DIAMETER OF THE AXLE THE POWER INCREASE IS _____.

13. Rotate the wheel until the 1-ounce weight is even with one of the rows of holes in the pegboard (probably Row 11).

14. Notice the location of the bottom of the three 1-ounce weights and pull the 1-ounce weight down three rows of holes. The three 1-ounce weights will move up about one row.

THIS SHOWS THAT WITH A WHEEL AND AXLE SET, WHERE THE WHEEL IS THREE TIMES THE DIAMETER OF THE AXLE THE FORCE MOVES THREE TIMES THE DISTANCE OF THE _____.

15. Remove all the weights from both strings and the string from the blue wheel.

16. Rotate the wheel and axle set so the opening in the rim of the 4 1/2-inch yellow wheel is on the right hand side.

17. Attach the loop of the 18-inch string to the hook of the yellow wheel and lead it out through the opening in the rim opposite the hook.

18. Hold the wheel in place and put one 1-ounce weight on the string from the yellow wheel.

19. Put two 3-ounce weights on the string from the axle and add 1-ounce weights until the wheel and axle set balances. It should balance when three 1-ounce weights have been added. (Refer to Note on page 56-3.)

THIS SHOWS THAT WITH A WHEEL AND AXLE SET, WHEN THE WHEEL IS NINE TIMES THE _____ OF THE AXLE THE POWER INCREASE IS NINE.

20. Rotate the wheel until the 1-ounce weight is as high as it will go, about Row 6.

21. Notice the location of the bottom of the nine ounces of weight and pull the 1-ounce weight down nine rows of holes. The nine ounces of weight will move up about one row.

THIS SHOWS THAT WITH A WHEEL AND AXLE SET, WHERE THE WHEEL IS NINE TIMES THE DIAMETER OF THE AXLE THE FORCE MOVES NINE TIMES THE _____ OF THE LOAD.

QUESTIONS

1. If a wheel is three times bigger than the axle, the mechanical advantage is _____ to one.

2. If a wheel is nine times bigger than the axle, the mechanical advantage is _____ to one.

3. If an automobile tire has a diameter of 24 inches and the axle is two inches in diameter, the mechanical advantage is _____ to one.

4. If larger tires (in diameter) were put on an automobile, it would require _____ power from the engine to move the car.

5. If smaller (in diameter) tires were put on an automobile, it would require _____ power from the engine to move the car.

6. In Question 4 above, for every turn of the axle the car would move _____ with each turn of the axle.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 7

The George Washington University
Education Research Project
1966

BELTS, PULLEYS, AND BEVEL GEARS

Objectives

To develop an understanding of the principles of belt and pulley operation.

To understand the operation of bevel gears.

Materials

Item No.	Quantity	Description
1	2	3-Step Pulley
2	2	2" Long #10 Machine Screws and Matching Nuts
3	5	Large Rubber Bands
4	1	Bevel Gear Set
5	1	2-Step Pulley
6	1	Pegboard Hook

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.
2. Be very careful that the pulleys line up properly or the belt will not stay in place.
3. Emphasize that in any belt-pulley set-up there is always a Driver Pulley and a Driven Pulley.
4. Relate the pulley and belt set-up to simple machines such as: a piston type pump where the pump must turn slower than the motor (large pulley on the pump), a ventilator fan (the fan turns slower), the fan on an automobile (about the same speed), the tuning dial on a radio (the pointer must move slower), or a belt-driven dentist's drill (the drill turns faster).

5. Emphasize these points:
   a. When the drive is from the large pulley to the small pulley the result is an increase in speed.
   b. When the drive is from the small pulley to the larger pulley the result is an increase in power.

6. A pegboard hook mounting is used for the two-step pulley to facilitate easier alignment and placement of the pulley when students may wish to develop their own set-ups in Step 11.

7. Answers to the blanks in the stated principles in the STUDENT'S MANUAL:

   SP-2 [redacted]
   SP-2 [redacted]
   SP-2 [redacted]
   SP-3 [redacted]
   SP-3 [redacted]
   SP-3 [redacted]
   SP-4 [redacted]
   SP-5 [redacted]
   SP-5 [redacted]

8. Answers to Questions in Student's Exercise:

   1. same
   2. opposite
   3. larger
   4. speed
   5. power
   6. right
   7. power

BELTS, PULLEYS, AND SPUR GEARS

Purpose

To understand the operation of a belt and pulley system and the operation of bevel gears.

Materials

Item No.	Quantity	Description
1	2	3-Step Pulley
2	2	2" Long #10 Machine Screw
3	5	Large Rubber Bands
4	1	Bevel Gear Set
5	1	2-Step Pulley
6	1	Pegboard Hook

Step-by-Step Procedure

Preparing materials and setting up the board

1. Mount one machine screw in Row 13, hole L, with the head in the back of the board and the nut in front.
2. Mount the other machine screw in Row 13, hole P, with the head in the back of the board and the nut in front.
3. Slide one 3-Step Pulley over each of the screws with the small pulley facing you.

Working with pulleys

4. Stretch a rubber band (belt) over the two small (blue) pulleys.
5. Make a mark with a pencil or grease pencil on both of the blue pulleys.
6. Rotate the right hand pulley one turn and notice how many times the left hand pulley turns.

NOTE: The pulley you turn is known as the Driver Pulley and the other one is the Driven Pulley.

7. Move the belt (rubber band) to the red pulley on both shafts and repeat Step 6.

8. Move the belt to the yellow pulleys and repeat Step 6.

THIS SHOWS THAT WITH PULLEYS OF
EQUAL SIZE THE DRIVEN PULLEY WILL
TURN THE SAME NUMBER OF _____
AS THE DRIVER PULLEY.

9. Rotate the right hand pulley in a clockwise direction and notice the direction of rotation of the left hand pulley.

THIS SHOWS THAT WHEN PULLEYS ARE
CONNECTED BY A STRAIGHT BELT THEY
BOTH TURN THE _____ DIRECTION.

10. Connect the belt from the blue pulley on the right hand side to the blue pulley on the left hand side but put a single half turn in belt (the belt should look like a figure 8).

11. Rotate the right hand pulley in a clockwise direction. Notice the direction of rotation of the left hand pulley.

THIS SHOWS THAT WHEN PULLEYS ARE
CONNECTED BY A CROSSED BELT THEY
TURN IN _____ DIRECTIONS.

12. Connect the blue pulley on the right to the red pulley on the left with the belt straight across.

NOTE: When connecting pulleys of different size it will be necessary to slide the pulley in or out on the shaft to line it up with the other pulley.

13. Rotate the blue pulley until the mark made in Step 5 is on top.

14. Make a mark on the top of the red pulley.

15. Rotate the right hand blue pulley one turn and notice the red pulley has turned about 2/3 of a turn.

16. Repeat Steps 13-14-15, but with the belt connected from the right hand blue pulley to the left hand yellow pulley.

17. Observe the large yellow pulley turns a little less than 1/2 turn for each complete turn of the blue pulley.

THIS SHOWS THAT WHEN PULLEYS OF UNEQUAL DIAMETER ARE CONNECTED THE LARGER PULLEY TURNS FEWER TIMES THAN THE _____ PULLEY.

18. Turn the left hand pulley (the belt should still be connected from the large left hand pulley to the small right hand pulley) one complete turn. Notice the small right hand blue pulley turns much faster than the left hand yellow pulley.

THIS SHOWS THAT WHEN THE DRIVE IS FROM A LARGE PULLEY TO A SMALLER PULLEY, THE RESULT IS AN _____ IN SPEED (REVOLUTIONS PER MINUTE) AND A DECREASE IN POWER.

19. Repeat Step 18 but turn the right hand pulley one turn. Notice the large left hand yellow pulley turns fewer times.

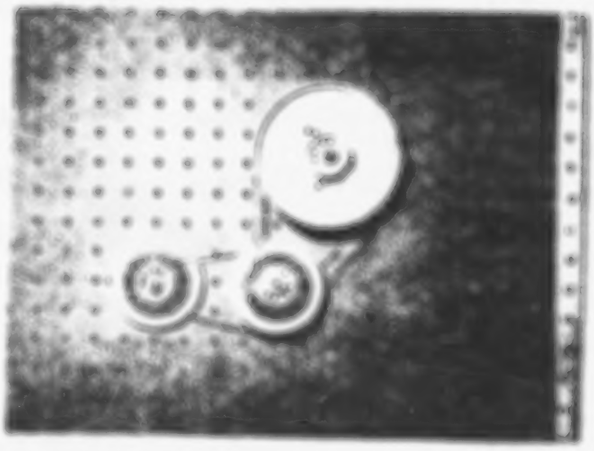
THIS SHOWS THAT WHEN THE DRIVE IS FROM A SMALL PULLEY TO A LARGER PULLEY, THE RESULT IS A _____ IN SPEED (R.P.M.) AND POWER IS INCREASED.

Working with compound pulleys

20. Take the 3-Step Pulley and mount it with the pegboard nuts in Row 9, holes P and Q.

21. Connect a belt from the blue pulley on the shaft in Row P to the large yellow pulley on the wheel and axel set.

22. Notice the results when the large pulley is rotated one turn and when the small pulley is rotated one turn.



23. Remove the belt.

24. Connect a belt from the blue pulley on the shaft in Row L to the yellow pulley on shaft P.

25. Connect another belt the same way as Step 21.

26. Turn the left hand blue pulley and notice how slowly the large yellow pulley turns.

27. Turn the large yellow pulley and notice how fast the small blue pulley on the left hand side turns.

THIS SHOWS THAT A COMPOUND BELT AND PULLEY SET-UP CAN BE MADE USING THREE PULLEYS THAT WILL RESULT IN A LARGE _____ IN SPEED OR POWER.

Working with bevel gears

28. Take the bevel gear unit and notice the form of the teeth. This type of gear is used to transmit power at right angles.

29. Make a mark with a pencil or grease pencil on both gears.

30. Rotate the small gear one complete turn. Notice that the large gear turns about one-quarter of a turn.

THIS SHOWS THAT WHEN POWER IS APPLIED TO THE SMALL GEAR THE LARGE GEAR WILL TURN _____.

M. Rotate the large gear one complete revolution and notice the small gear turns around about four times.

THIS SHOWS THAT WHEN POWER IS APPLIED TO THE LARGE GEAR THE SMALL GEAR WILL TURN _____.

N. If time permits, any combination of pulleys may be worked out using the three pulleys.

QUESTIONS

1. Pulleys connected by a straight belt turn the _____ direction.

2. Pulleys connected by a crossed belt turn _____ directions.

3. If a large pulley and a small pulley are connected, the _____ pulley will always turn fewer times.

4. A belt and pulley system driving from a large pulley to a small pulley will give an increase in _____.

5. A belt and pulley system driving from a small pulley to a large pulley will give an increase in _____.

6. Bevel gears are used to transmit power at _____ angles.

7. A compound belt and pulley set-up with three pulleys will give a large increase in either speed or _____.

THE INCLINED PLANE

Objective

To demonstrate what an inclined plane is and how it works.

Materials

Item No.	Quantity	Description
1	1	Friction Block
2	1	Friction Platform
3	2	1-ounce Weights
4	1	4-ounce Weight
5	2	S Hooks
6	1	15-inch String
7	2	Friction Platform Hooks
8	1	Spring Scale
9	1	Paper Clip Hook
10	1	Toy Car
11	1	Single Pulley
12	25	Washers, 1/4" diameter hole
13	1	Pegboard Hook

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.
2. The procedure has been designed to allow and facilitate discussion at each stage from the beginning.
3. Student comment and discussion is desirable throughout the demonstration.
4. Encourage discussion by asking questions and making comments about what is being demonstrated and how it relates to tools and machines one sees in the environment.
    a. Have the students name examples of the inclined plane they have seen, such as earth ramp to an excavation for a new building, ramp for wheel chair in hospitals, boards used for moving objects in and out of trucks or buildings, etc.

b. Bring out the relationship that exists between what was done in the exercise on friction and this exercise on the inclined plane.

5. If there is time in the class period, the student may be permitted to do optional experimentation suggested in Step 31 or others the teacher and students might think are interesting and worthwhile.

6. The following principles have been demonstrated in this exercise:
   a. Little force is required to move an object horizontally when wheels are used.
   b. An object may be moved more easily over a level surface than up an inclined plane.
   c. The greater the slope the harder it is to move an object up an inclined plane.

7. The procedure, Steps 10-12-16-18-22-24-27 and 29, suggests making a record of the observations of weights and scale readings. A sample Record of Observations form is included in the STUDENT'S MANUAL. The teacher and students may wish to devise their own form.

8. Answers to blanks in the stated principles in the STUDENT'S MANUAL
   35-3 WHEELS
   35-4 LESS
   35-5 MORE
   35-6 GREATER

9. Answers to Questions in Student's Exercise:
   1. inclined plane
   2. little
   3. inclined plane
   4. greater
   5. less

THE INCLINED PLANE

Purpose

This exercise will help you understand how the inclined plane works.

Materials

Item No.	Quantity	Description
1	1	Friction Block
2	1	Friction Platform
3	2	1-ounce Weights
4	1	4-ounce Weight
5	2	S Hooks
6	1	18-inch String
7	2	Friction Platform Hooks
8	1	Spring Scale
9	1	Paper Clip Hook
10	1	Toy Car
11	1	Single Pulley
12	25	Washers, 1/4" diameter hole
13	1	Pegboard Hook

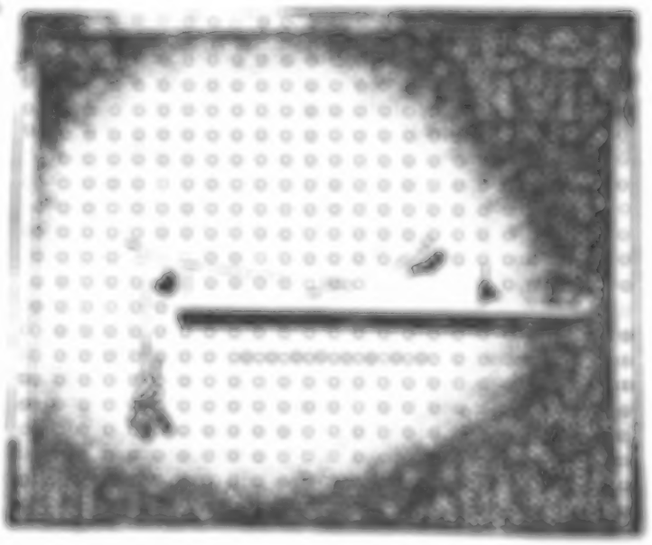
Step-by-Step Procedure

Preparing materials and setting up the board

1. Insert pegboard hooks in the holes in one side of the platform. The half-round molding is on the upper side of the platform.
2. Put the friction platform on the pegboard so that it is horizontal and about in the center of the eleventh row of holes from the top. The hooks should be in Row 9, holes 5-7.
3. Place the pegboard hook in Row 9, hole 5-F.
4. Slide the pulley over the long pegboard hook.
5. Make a loop in each end of the 18-inch piece of string. Do this by doubling one end of the string back about four inches and tying a single knot in the doubled end. Then do the same thing on the other end.

6. Get a rough estimate of the weight of the friction block by weighing it with the spring scale. Write the weight on the side of the block. Notice that the block weighs a little more than one ounce.

Moving objects along a horizontal plane



7. Place one 4-ounce weight in the two holes of the friction block.

8. Attach one loop of the string in the hook of the block and put an S hook in the other end.

9. Place the block and weights on the end of the platform away from the half-round molding with the S hook hanging over the pulley.

10. Hang two 1-ounce weights and add washers on a paper clip hook to the S hook until the block moves. Make a note on Page 38-5 of how much weight it takes to keep the block moving. Each time weight is added, push the block gently from behind to see whether or not you have enough weight to keep it moving after it has been started.

11. Remove the S hook and weights and insert the hook of the spring scale.

12. Pull the block with the spring scale, so that the string is over the pulley, along the platform horizontally, observing the reading as you do so. Make a note of the scale reading on Page 38-5.

13. Remove everything from the platform and take the scale from the string.

14. Remove the 4-ounce weight from the block and place it on the seat of the toy car.

NOTE: The weights will stay in place better if Scotch tape is used.

15. Attach a string with an S hook to the front of the car and lead it over the pulley. Attach an S hook to the loop hanging over the pulley.

16. Hang washers on the S hook until the car moves. Make a note on Page 28-5 of how many washers it took to keep the car moving.

THIS SHOWS THAT IT TAKES SOME LITTLE
FORCE TO MOVE AN OBJECT HORIZONTALLY
WHEN _____ ARE USED.

17. Remove the S hook and washers and insert the hook of the spring scale.

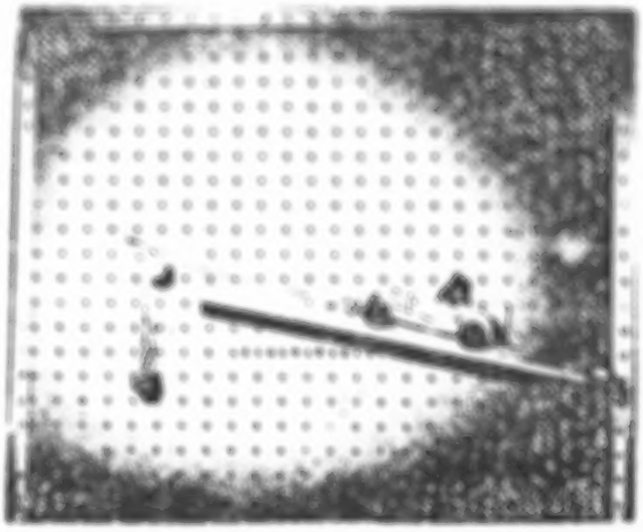
18. Pull the car along the platform horizontally, observing the reading as you do so. Make a note of this reading on Page 28-5.

19. Remove everything from the platform and take the scale from the string.

Moving an object along an inclined plane of little slant

20. Leave the platform hook on the end near the pulley where it is. Lower the other platform hook down two holes to Row 11. (This is approximately a 10-degree angle.)

21. Place the car with one 4-ounce weight on the seat of the car on the platform.



NOTE: The end of the string away from the car will have to be held with one hand until weight is placed on the S hook, otherwise the weight will cause the car to roll off the platform.

22. Hang a 1-ounce weight and add washers on the S hook until the car moves. Make a note on Page 38-5 of how much weight is taken to keep the car moving.

THE CAR WEIGHS MORE THAN FOUR OUNCES
AND IS MOVED UP THE INCLINED PLANE
BY A PUSH _____ POUNDS.

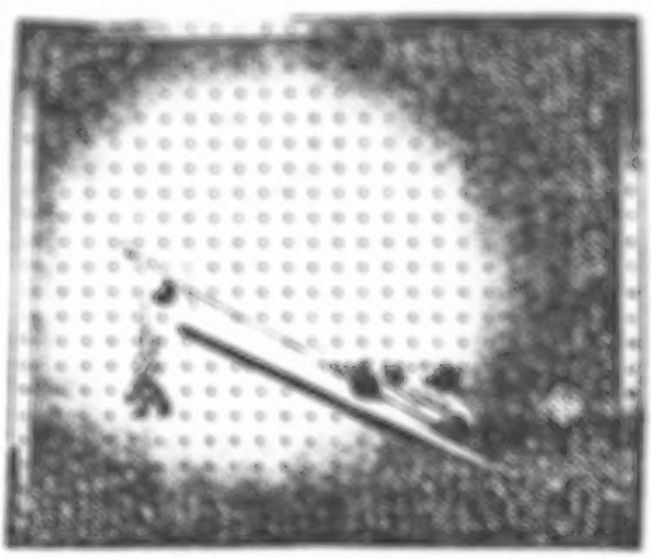
23. Remove the S hook and weights and insert the hook of the spring scale.

24. Pull the car up the platform, observing the reading as you do so. Make a note of this reading on Page 38-5.

25. Remove everything from the platform and take the scale from the string.

Moving an object along an inclined plane of greater slant

26. Leave the platform hook on the end near the pulley where it is. Move the other platform hook down three holes and one hole toward the center, Row 14, hole 8. (This is approximately a 25-degree angle.)



27. Hang weights and washers on a paper clip hook on the S hook until the car moves. Try two 1-ounce weights first. Make a note on the chart of how much weight it took to keep the car moving.

POSITION OF PLATFORM	OBJECT AND ADDED WEIGHT	READINGS	
		WEIGHTS	SCALES
Horizontal	Block plus 4 ounces		
Horizontal	Car plus 4 ounces		
Slight Slope	Car plus 4 ounces		
Steep Slope	Car plus 4 ounces		

THIS SHOWS THAT WHEN THE INCLINED PLANE IS STEEPER, IT TAKES _____ EFFORT TO MOVE A WEIGHT UP IT.

28. Remove the 5 hook and weights and lower the hook of the spring scale.

29. Pull the car up the platform, observing the reading as you do so. Make a note of this on the chart.

30. Remove everything from the platform and take the scale from the string.

THIS SHOWS THAT THE _____ THE SLOPE THE HIGHER IT IS TO MOVE AN OBJECT UP AN INCLINED PLANE.

Additional experiments

31. If there is time, you might like to work with objects other than the smooth block and the car. Using the slopes suggested in Steps 2-20 and 26, the following objects, or ones you think suitable, may be used:

a. blackboard eraser
b. pencil case
c. bracelet
d. box of crayons
e. paperweights

NOTE:	You may either fasten these objects to the block or place them on the platform without the block.

QUESTIONS

1. A plank, road, or ramp that slants from the ground or floor to a higher level is known as an _____ _____.

2. It takes very _____ force to move an object horizontally when wheels are used.

3. It is easier to move an object horizontally along the ground or floor than up an _____ _____.

4. When an object is moved up an inclined plane, the greater the slant of the plane, the _____ the force needed.

5. When the slant is reduced, it takes _____ force to move an object up an inclined plane.

The George Washington University
Education Research Project
1966

THE PULLEY

Objective

To demonstrate how pulleys work.

Materials

Item No.	Quantity	Description
1	2	Pulleys, single
2	2	Pulleys, double
3	2	Fastener Hooks
4	6	1-ounce Weights
5	1	18-inch String
6	1	36-inch String
7	4	S Hooks
8	1	Spring Scale

Suggestions to the Instructor

1. Follow the procedure in the STUDENT'S MANUAL, starting at the Step-by-Step Procedure section.

2. Call attention of the class to the fact that sometimes pulleys are called blocks, and the ropes are called tackle.

3. Encourage student participation by having them come up in groups to the demonstration table, by asking questions, by making comments and discussing aspects of the exercise.

4. The teacher may refer, through questions and comments, to the relationship of the exercise and its application to tools and machines in the environment.
   a. Examples of the use of single fixed pulleys:
      pulley in the flag pole, pulley in window sash, and well pulley.
   b. Examples of the use of single movable pulleys:
      pulley for loading cargo on ships, and pulley for raising and lowering heavy weights into an excavation.
   c. Examples of pulley combinations:
      multiple wheeled blocks used on ships, in cranes, and in hoisting and lowering lifeboats.

5. Point out to the students that by using various combinations of fixed and movable pulleys a mechanical advantage is achieved. The mechanical advantage of any system of pulleys is equal to the number of strings or rope strands used to support the pulley(s) bearing the load. When two strands are used to support the load, the mechanical advantage is two. When three strings are used, the mechanical advantage is three, and so on. Also point out that as much energy is expended in one pulley system as another; however, the work is made easier. For example, the force required to move a load supported by four strands, although one-fourth the load, must travel four times the distance in moving the load.

6. If there is time in the class period, the students may be permitted to do the additional procedures suggested in Steps 59 through 63.

7. The following principles have been demonstrated by this exercise:
   a. With the single fixed pulley, the force and the load balance when equal.
   b. Also with the single fixed pulley, the force moves the same distance as the load.
   c. With the single movable pulley, the amount of force required to balance the load is approximately one-half the load.
   d. Also with the single movable pulley, the force moves twice as far as the load.
   e. With pulley combinations, when three strings are used to support the load, the amount of force required to balance the load is one-third the load.
   f. Also with pulley combinations, when three strings are used to support the load, the force moves three times as far as the load.
   g. With pulley combinations, when four strings are used to support the load, the amount of force required to balance the load is one-fourth the load.
   h. Also with pulley combinations, when four strings are used to support the load, the force moves four times as far as the load.

8. Answers to the blanks left in the stated principles in the STUDENT'S MANUAL:

S9-2	EQUAL	
S9-2	LOAD	
S9-3	ONE-HALF	
S9-3	TWICE	
S9-4	THREE	
S9-4	FORCE	
S9-5	ONE-FOURTH	
S9-6	ONE-FIFTH	(63a)
	FIVE	(63b)

9. Answers to the Questions on Page S9-7 of the STUDENT'S MANUAL:

1. Single fixed pulley
   a. equal or the same
   b. the same or equal
2. Single movable pulley
   a. one-half
   b. twice or two times
3. Pulley combinations
   a. one-third
   b. one-fourth
   c. three times
   d. four times

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 9

The George Washington University
Education Research Project
1956

THE PULLEY

Purpose

This exercise will help you understand how pulleys work.

Materials

Item No.	Quantity	Description
1	2	Pulleys, single
2	2	Pulleys, double
3	2	Pegboard Hooks
4	6	1-ounce Weights
5	1	18-inch String
6	1	36-inch String
7	4	S Hooks
8	1	Spring Scale

Step-by-Step Procedure

Working with the single fixed pulley (See Figure 1)

1. Put a wire pegboard hook in the middle of the pegboard, Row 3. Bend the hook down so that it is level.
2. Hang an S hook from the pegboard hook.
3. Hang a single pulley from the S hook.
4. Tie a loop in the ends of the 18-inch piece of string. Do this by doubling the string back about two inches and tying a simple knot in doubled end.
5. Run the string over the top of the pulley hanging from the pegboard hook. Let half of the string hang on each side.

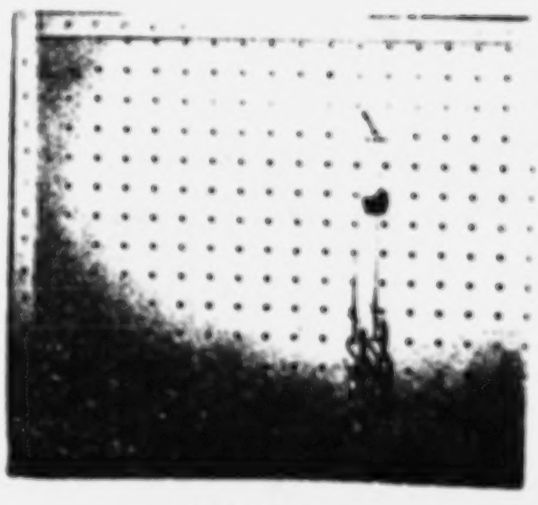


FIGURE 1

6. Insert an S hook in the loop at each end of the string.
7. Hang one 1-ounce weight from each of the S hooks. Observe that they balance each other.

8. Repeat Step 7 using three 1-ounce weights on each S hook. Observe that equal weights balance each other.

THIS SHOWS THAT WITH THE SINGLE FIXED PULLEY,
THE FORCE AND THE LOAD BALANCE WHEN THEY ARE _____.

9. Slide the S hook supporting the pulley and weights back until it is about one inch from the pegboard.

10. Push one of the weights up as close to the pulley wheel as it will go. Note the number of the row at the bottom of the weight.

11. Pull the higher weight down as far as it will go. Notice the row number at the bottom of the weight. Compare the distance each weight moves. Notice they move the same distance.

THIS SHOWS THAT WITH THE SINGLE FIXED PULLEY,
THE FORCE MOVES THE SAME DISTANCE AS THE _____.

Working with a single movable pulley (See Figure 2)

12. Remove all materials from the pegboard.

13. Put one pegboard hook in Row 9, holes M-O.

14. Put another pegboard hook in Row 3, holes K-L.

15. Hang the spring scale on the hook in Row 3.

16. Hang an S hook from the pegboard hook.

17. Insert an S hook in the hole of the single pulley.

18. Using the 18-inch string with the two loops in it (Step 4), place one of the loops on the S hook of the right pegboard hook.

19. Hang the other loop of the string over the hook of the spring scale.

20. Hang the pulley over the string with the S hook hanging down.

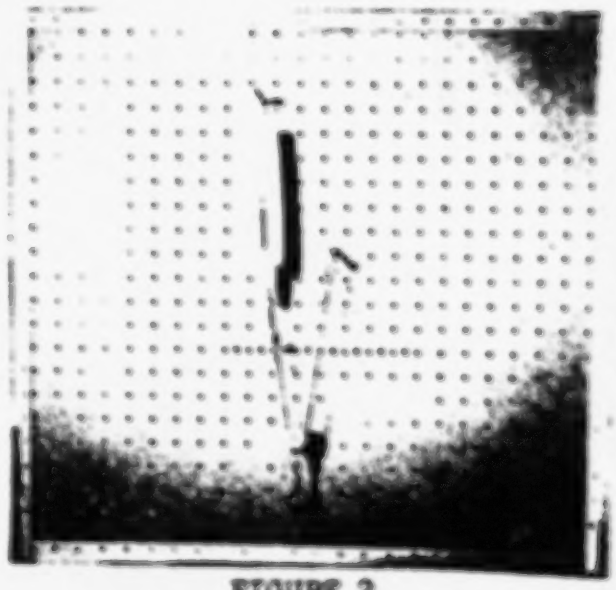


FIGURE 2

21. Notice the reading on the spring scale (about 1/2-ounce).

22. Hang a 1-ounce weight on the S hook of the pulley. Notice the weight on the spring scale (about 1-ounce).

23. Hang two or three additional 1-ounce weights on the S hook, one at a time, and notice that the weight gain on the spring scale is only 1/2-ounce for each ounce added.

THIS SHOWS THAT WITH A SINGLE MOVABLE PULLEY,
THE AMOUNT OF FORCE REQUIRED TO BALANCE THE
LOAD IS _____ THE LOAD.

24. Slide the spring scale and the S hook back until they are about one inch from the pegboard.

25. Notice the row of holes near the top of the movable pulley and the row of holes near the bottom of the hook of the spring scale.

26. Push the pulley down one row of holes and notice that the hook of the spring scale moves down about two rows of holes.

THIS SHOWS THAT WITH THE SINGLE MOVABLE PULLEY,
THE FORCE MOVES _____ AS FAR AS THE LOAD.

<u>Working with pulley combinations with three supporting strings</u>

27. Remove all fixtures from the pegboard.

28. Place one pegboard hook in Row 1, holes O and P.

29. Place another pegboard hook in Row 1, holes K and L.

30. Hang the spring scale over the pegboard hook on the left.

31. Hang a double pulley from the right pegboard hook. (The larger hole in the pulley will fit over the pegboard hook.)

32. Tie a loop in each end of the 36-inch string the same way as was done with the 18-inch string.

33. Using an S hook attach one end of the string to the other double pulley.

34. Lead the string from the S hook over the upper pulley of the double pulley on the pegboard hook from left to right.

35. Run the string under the upper pulley of the unattached pulley from right to left.

36. Put the loop of the string over the hook on the spring scale.

37. Notice the reading on the spring scale (about 1/2-ounce).

38. Using an S hook attach three 1-ounce weights to the lower pulley.

39. Notice the reading on the spring scale (about 1 1/2-ounces). There are three strings supporting the load.

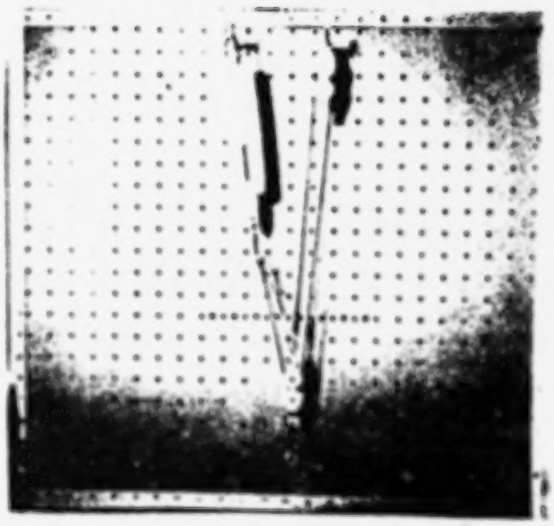


FIGURE 1

THIS SHOWS THAT WITH PULLEY COMBINATIONS, WHEN _____ STRINGS ARE USED TO SUPPORT THE LOAD, THE AMOUNT OF FORCE REQUIRED TO BALANCE THE LOAD IS ONE-THIRD THE LOAD.

40. Slide the upper pulley and the spring scale back until they are about one inch from the pegboard.

41. Remove the string from the spring scale and hold it level with Row 3 on the board, directly under the pegboard hook.

42. Notice which row of holes is level with the bottom of the weights.

43. Move the string in your hand down to Row 6.

44. Notice that the weights have only moved down one row.

THIS SHOWS THAT WITH PULLEY COMBINATIONS, WHEN THREE STRINGS ARE USED TO SUPPORT THE LOAD, THE _____ MOVES THREE TIMES AS FAR AS THE LOAD.

Pulley combinations with four strings (See Figure 4)

45. Remove all fixtures from the pegboard hook.

46. Using an S hook, hang one of the double pulleys from the pegboard hook.

47. Using another S hook, place four 1-ounce weights on the other double pulley.

48. Place an S hook in the hole at the lower end of the pulley hanging from the pegboard hook.

49. Place the loop of one of the ends of the 36-inch string over the S hook of the pulley hanging from the pegboard hook.

50. Lead the other end of the string on the right side of the other double pulley and under the top wheel above the weights.

51. Run the string up to the other double pulley so that it runs from left to right on the lower wheel. The string now hangs on the right side.

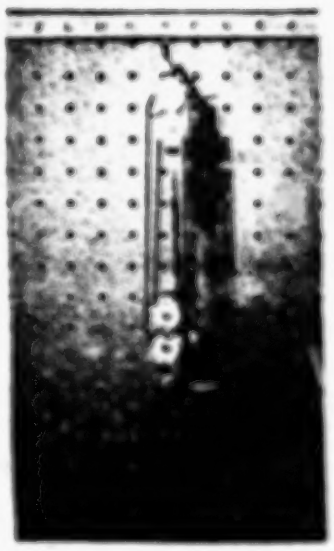


FIGURE 4

52. Run the string under the wheel of the other double pulley which is directly above the weights.

53. Pull the string out on the left side. Run it up to and over the top of the upper wheel of the double pulley hanging from the pegboard hook.

54. Pull the string out on the right side. Insert an S hook in the loop of the string.

55. Hang a 1-ounce weight from the S hook. Notice that the 1-ounce weight balances the four 1-ounce weights. Observe also that there are four strings supporting the movable double pulley.

THIS SHOWS THAT WITH PULLEY COMBINATIONS, WHEN FOUR STRINGS ARE USED TO SUPPORT THE LOAD, THE AMOUNT OF FORCE REQUIRED TO BALANCE THE LOAD IS _____ THE LOAD.

56. Slide the S hook supporting the pulleys and weights back until it is about one inch from the pegboard.

57. Push the 1-ounce weight up as close to the pulley wheel as possible. Notice the row of holes at the bottom of both of the weights.

58. Pull the 1-ounce weight down to Row 5. Check the distance the four 1-ounce weights have moved. Notice the 2-ounce weight moves four times as far as the two 4-ounce weights.

THIS SHOWS THAT WITH PULLEY COMBINATIONS, WHEN FOUR STRINGS ARE USED TO SUPPORT THE LOAD, THE FORCE MOVES FOUR TIMES AS FAR AS THE LOAD.

Additional experiences (See Figure 5)

59. Remove all the fixtures from the pegboard except the pegboard hook.

60. If you have time, you may set up your equipment as shown in Figure 5.

61. Repeat Steps 37-38-39.

62. Measure the distance the weights move as you did in Steps 40 through 44.

63. How would you complete the following statement after doing Steps 60-61-62?
    a. With pulley combinations, when five strings are used to support the load, the force required to balance the load is _____ the load.
    b. With pulley combinations, when five strings are used to support the load, the force travels _____ times as far as the load.

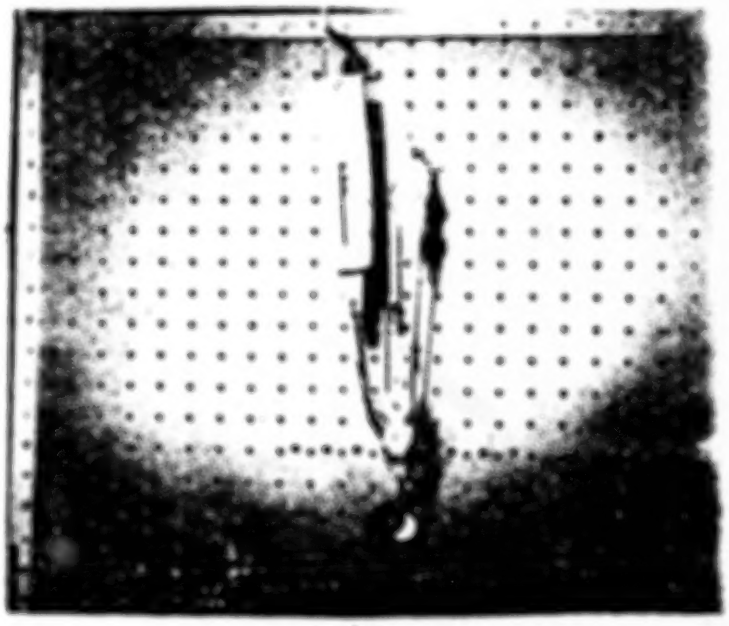


FIGURE 5

QUESTIONS

1. Single fixed pulley:
   a. When balanced, the force and the load are _____.
   b. The force moves _____ _____ distance as the load.

2. Single movable pulley:
   a. The amount of force required to move the load is _____ the load.
   b. The force moves _____ as far as the load.

3. Pulley combinations:
   a. When three strings are used to support the load, the amount of force required to balance the load is _____ the load.
   b. When four strings are used to support the load, the amount of force required to balance the load is _____ the load.
   c. When three strings are used to support the load, the force moves _____ _____ as far as the load.
   d. When four strings are used to support the load, the force moves _____ _____ as far as the load.

Laboratory Training Exercise
TEACHER'S MANUAL
Exercise 10

The George Washington University
Education Research Project
1966

DETERMINING WEIGHTS

Objective

To develop an understanding and appreciation of the principles of a balance type of scale.

Materials

Item No.	Quantity	Description	Source
1	1	Lever Arm	Lever Kit
2	2	Paper Clip Hooks	Lever Kit
3	1	1-ounce Weight	Inclined Plane
4	30	Washers, 1/4" diameter hole	Inclined Plane
5	1	Friction Block	Inclined Plane
6	1	Toy Car	Inclined Plane
7	1	Spring Scale	Inclined Plane
8	1	Pegboard Hook	Inclined Plane

Suggestions to the Teacher

1. This is an optional exercise that may be performed if the students show an interest and the time is available.
2. Follow the procedure in the STUDENT'S MANUAL starting at the Step-by-Step Procedure section.
3. The procedure has been designed to allow for student comment and facilitate the teacher's discussion.
4. The balance scale is the type very frequently seen in candy stores, doctor's offices, and drug stores. Encourage students to relate experiences they have had with this type of scale.
5. The chart used in Steps 9-12-16-21-25 on Page T10-4 will probably require an additional explanation. Demonstrate how fractions are reduced when the number of washers is multiplied by the distance factor. Emphasize the fact that washers and weights cannot be multiplied together.

6. Relate the mathematics of the balance scale to the Exercise 5 on Levers.

7. The following principles have been demonstrated in this exercise:
   a. The length of the load arm and the force arm affect the accuracy of the scale.
   b. Objects heavier than the weights available can be weighed by changing the length of the arms.

8. Answers to the blanks in the stated principles in the STUDENT'S MANUAL:

   S10-2 1/24 OUNCE (This will depend on student's exact findings.)
   S10-2 MORE
   S10-3 ONE-HALF
   S10-3 ONE-THIRD

9. Answers to Questions in Student's Exercise:
   1. more
   2. closer

Laboratory Training Exercise
STUDENT'S MANUAL
Exercise 10

The George Washington University
Education Research Project
1966

DETERMINING WEIGHTS

Purpose

To understand the operation of a simple balance type scale.

Materials

Item No.	Quantity	Description	Source
1	1	Lever Arm	Lever Kit
2	2	Paper Clip Hooks	Lever Kit
3	1	1-ounce Weight	Inclined Plane
4	30	Washers, 1/4" diameter hole	Inclined Plane
5	1	Friction Block	Inclined Plane
6	1	Toy Car	Inclined Plane
7	1	Spring Scale	Inclined Plane
8	1	Pegboard Hook	Inclined Plane

Step-by-Step Procedure

Setting up the board

1. Put the 6-inch wire pegboard hook in two of the holes in the middle of Row 8.
2. Using the 0 hole, hang the lever arm on the pegboard mounting hook. The lever arm balances if it is approximately level.
3. Hang the two paper clip hooks from hole 7 in each end of the lever arm. Is the arm now level, or does one end dip more than the other?
4. Exchange the two hooks. Does it balance better than before?
5. Leave the hooks in whichever hole gives the best balance.

Weighing objects of about 1-ounce

6. Remove the paper clip hook from one end of the lever arm and hang 25 washers over the hook.
7. Hang the paper clip hook with the 25 washers on it in hole 7 and hang a 1-ounce weight on the opposite hole 7.

8. Add washers or remove them until the arm is approximately level.

9. Remove both the weight and the washers and count the washers (approximately 22-26). Record this on the chart on Page S10-4.

THIS SHOWS THAT EACH WASHER WEIGHS
ABOUT _____ OF AN OUNCE.

10. Hang the friction block on one end of the lever arm and hang a 1-ounce weight on the other.

11. Add washers on the side with the weight until the lever arm balances.

12. Remove the weights and friction block and count the washers. Record on the chart the weight of the block.

13. Put the friction block and the weights in hole 1 on either side of the pegboard hook.

14. Add washers one at a time to the weight side. Notice that you can add five or six more washers before the balance changes.

15. Remove the washers added in Step 14 and remove more washers one at a time. Notice you can remove about three or four more before the balance changes.

THIS SHOWS THAT THE LONGER THE BALANCE
ARM OF A SCALE THE _____ ACCURATE
IT BECOMES.

16. Weigh the toy car by hanging it from hole 7 and balance it with a weight and washers in the other end of the balance arm. Record the weight on the chart on Page S10-4.

<u>Weighing objects greater than 1-ounce</u>

17. Place a paper clip hook in hole R3 and hole L6.

18. Hang the spring scale from hole R3.

19. Hang a 1-ounce weight from hole L6 and add washers until the arm is approximately level.

20. Remove the weights and count the washers.

21. Multiply the total weight (weight and washers) needed to balance the scale by two. This will give you the weight of the scale. Record this on Page S10-4.

WHEN THE FORCE IS TWICE AS FAR FROM THE FULCRUM AS THE OBJECT TO BE WEIGHED, THE FORCE NEEDED IS _____ THE LOAD.

22. Hang one paper clip hook from hole L6 and the other hook from hole R2.

23. Hang a 1-ounce weight from hole L6.

24. Hang an object of your own choosing from hole R2 (a number of keys, a small metal object, a notebook, or some other object you estimate to weigh between three and six ounces).

25. Determine the weight of the object by counting the weight and washers and multiplying by three and recording it on the chart.

WHEN THE FORCE IS THREE TIMES AS FAR FROM THE FULCRUM AS THE OBJECT TO BE WEIGHED, THE FORCE NEEDED IS _____ THE LOAD.

26. Weigh other objects of your choice. By moving the weights and the objects to be weighed in various holes in the lever arm, objects from 1/24 of an ounce to 1/2 pound (8 ounces) can be weighed with only 3 ounces of weight.

QUESTIONS

1. The longer the balance arms, the _____ accurate the scale becomes.

2. To weigh an object heavier than the weights available, you can move the object to be weighed _____ to the fulcrum.

OBJECT	WEIGHTS	WASHERS	MULTIPLY (FORCE DISTANCE DIVIDED BY LOAD DISTANCE)	TOTAL WEIGHT (REDUCE FRACTIONS)
1-ounce Weight			7/7 = 1	
Friction Block			7/7 = 1	
Toy Car			7/7 = 1	
Spring Scale			6/3 = 2	
Others			6/2 = 3	

Space for multiplying (multiply weights and washers separately, reduce improper fractions)